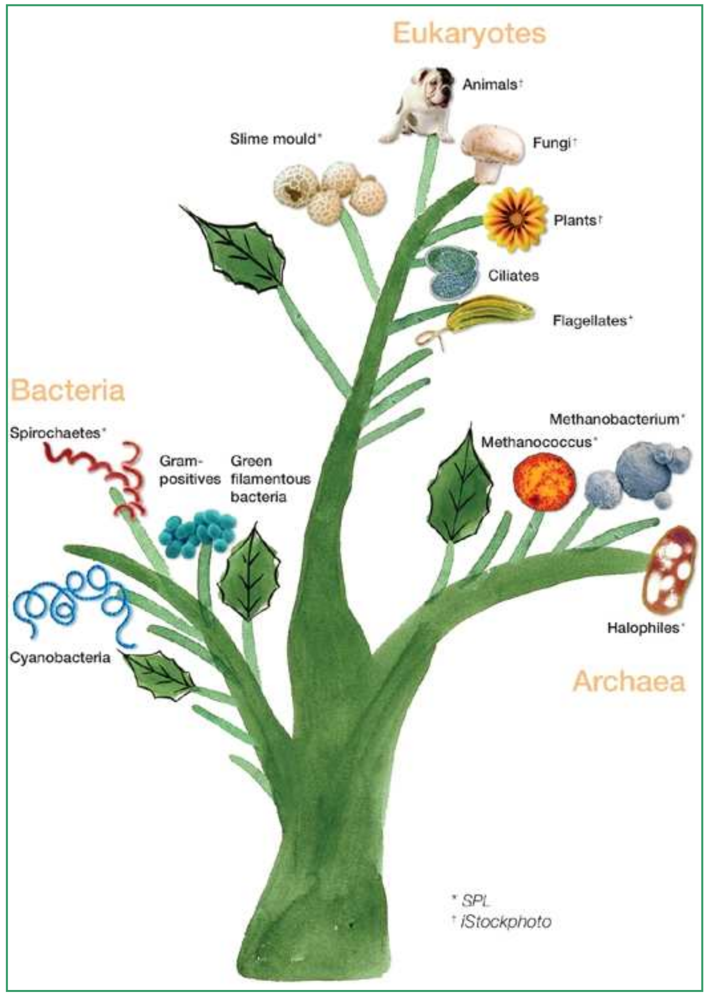
(Text from Modern Biology, Holt, Rinehart, and Winston)

Chapter Fifteen (Theory of Evolution)

SECTION ONE: HISTORY OF EVOLUTIONARY THOUGHT

The development of new types of organisms from preexisting types of organisms over time is called **evolution**. Modern scientists also define evolution as a change in the characteristics within a population from one generation to the next. After visiting the Galapagos Islands and noticing the variety of animal species there, Charles Darwin wanted to present evidence that evolution occurred. Darwin's theory became the basis for future explanations of evolution.



Ideas of Darwin's Time

During the 18th century, most European scientists believed that all species were permanent and unchanging. Additionally, they believed that the Earth was only thousands of years old. However, new evidence was being found that suggested that species have changed over time and that the Earth was much older than anyone had previously imagined.

Ideas about Geology

Scientists in Europe had begun studying rock layers, also known as **strata**. They found that strata re formed as new layers of rock are deposited over time, inferring that lower strata were formed first. These scientists also discovered fossils of different organisms in the strata.

Georges Cuvier, a French anatomist, gave convincing evidence that some organisms in the past were vastly different that organisms of today, and that some of them had become *extinct*, and ceased to exist after a certain point in time. He also found that deeper and older strata hold organisms that are increasingly different from living species. He also found many sudden changes in the kinds of organisms found in one rock stratum compared to the next. Cuvier promoted the idea of *catastrophism*, which states that sudden geologic catastrophes caused the extinction of large groups of organisms in the past.

(Text from Modern Biology, Holt, Rinehart, and Winston)

English geologist Charles Lyell thought that the geologic processes that have shaped Earth in the past continue to work in the same ways. His idea is called *uniformitarianism*. Charles Darwin read Lyell's writings, excited to find how well Lyell's ideas fit with his own observations and ideas.

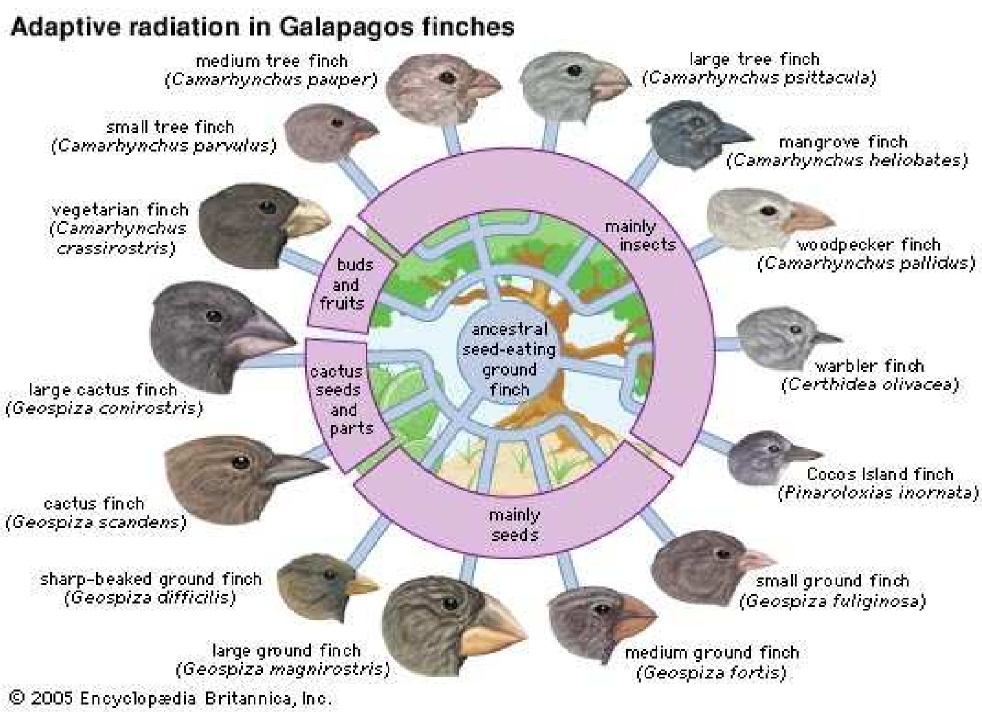
Lamarck's Ideas on Evolution

Jean Lamarck supported the idea that populations of organisms change over time. He put forth a new idea to explain how evolution occurred – he thought that simple organisms could arise from nonliving matter and that simple forms of life inevitably develop into more complex forms. He proposed that individuals could acquire traits during their lifetimes as a result of experience or behavior, and then pass on those traits to offspring. His idea is called the *inheritance of acquired characteristics*. However, his ideas are no longer accepted by scientists, since it has not been supported by modern scientific study.

DARWIN'S IDEAS

Descent with Modification

Darwin used the phrase *descent with modification* to describe the process of evolution. He reviewed the evidence that every species must have descended by reproduction from preexisting species and that species must be able to change over time. While not the first person to put forward the idea of descent with modification, Darwin was the first to apply it to all species.



The

animals of the Galapagos Islands were seen as evidence of descent with modification by Darwin. For example, the islands are home to thirteen different species. Each of these species has a beak that is best adapted for a certain kind of food. Darwin suspected that all thirteen species descended from the same ancestor, then diverged to better survive in the varied environments of the different islands.

Natural Selection

The theory of **natural selection** was proposed by Darwin as the mechanism for descent with modification.

1) **Overproduction** – More offspring can be produced than can survive to maturity. Since each new organism needs food and is vulnerable to predators and disease, not all of them live for very long. Economist Thomas Malthus pointed out that human populations can increase more quickly than food supply, but that populations are limited by the environment. Darwin drew this part of his theory from Malthus' idea, realizing that the environment limits the populations of all organisms by causing deaths or limiting births.
2) **Genetic Variation** – Within a population, individuals have different traits. For example, some giraffes have longer necks than others. These variations can be inherited; giraffes with long necks tend to have offspring with long necks. New traits can appear in a population.
3) **Struggle to Survive** – Individual must compete with each other in a "struggle for existence." Some variations allow organisms to have a better chance of surviving and reproducing. For example, giraffes with longer necks will be able to reach more leaves on trees than those with shorter necks. An **adaptation** is a trait that makes an individual successful in its environment.
4) **Differential Reproduction** – Darwin concluded that organisms with the best adaptations are most likely to survive and reproduce. Through inheritance, the adaptations will become more frequent in the population. Thus, populations may begin to differ if they become adapted to different environments, even if they descended from the same ancestors.

The theory of natural selection proposes that nature changes species by selecting traits. The environment "selects" the traits that may increase in a population by selecting the parents for each new generation.

Darwin also used the phrase "survival of the fittest" to describe his theory of natural selection. **Fitness** is a measure of an individual's hereditary contribution to the next generation – to be fit, an individual must have offspring that also live long enough to reproduce in a given environment. If a certain trait increases an organism's fitness, the proportion of organisms with that trait is likely to increase over time. In conclusion, adaptations are traits that increase the fitness of individuals, and populations tend to be well adapted to survive the conditions in which they live.

Adaptation is also used to describe changes in traits in populations over time, and is different from short-term adaptation by an individual to a temporary condition. *Acclimatization* is a short-term process in which physiological changes take place in an individual in its own lifetime – growing thicker fur in a cold climate. This is different from the adaptations discussed previously because this is not a variation caused by genetics.

A comparison between the ideas of Lamarck and Darwin is how giraffes acquired their long necks. In accordance to Lamarck's theory of *inheritance of acquired characteristics*, in stretching for the leaves on trees, some giraffes would make their necks slightly longer. Offspring of these giraffes would also have this slightly longer neck, and when they stretched, the necks would grow longer still. Over many generations, giraffes would have a long neck.

Darwin's idea of natural selection is depicted above. In the first picture, giraffes originally had short necks. However, because of genetic variation, some would have slightly longer necks. When food was scarce, individuals with longer necks would survive better because they could reach food that was unavailable to the others, thus decreasing competition. In the second picture, the giraffes would longer necks would survive, whereas the ones with shorter necks would not. The longer necked giraffes would survive to pass on the longer neck trait. Thus, their offspring have longer necks (third picture).

SECTION 1 REVIEW

1. Explain Darwin's use of the phrase *descent with modification* to describe the process of evolution.
2. Describe two scientists' ideas about geology that influenced ideas about evolution in the 1800s.
3. Explain the difference between an acquired characteristic and an inherited characteristic.
4. In what ways was Darwin an important scientist?
5. Describe the four parts of reasoning in Darwin's theory of evolution by natural selection. Use examples in your answer.

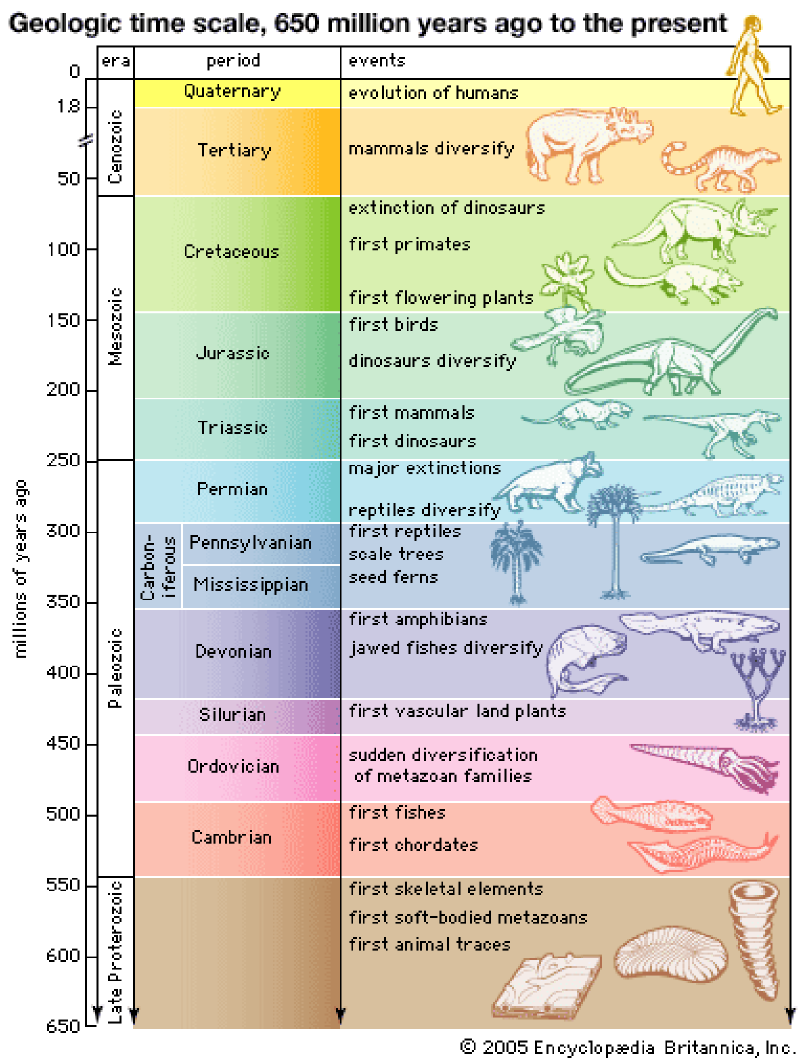
CRITICAL THINKING

6. Explain why some biologists say that "fitness is measured in grandchildren."
7. Suppose that an individual has a new trait that makes it live longer than others in its population. Does this individual have greater fitness? Explain your answer.
8. What have you learned about heredity and genetics that could support Darwin's theory of natural selection?

SECTION TWO: EVIDENCE OF EVOLUTION

THE FOSSIL RECORD

A **fossil** is the remains or traces of an organism that died long ago. Fossils of many kinds of organisms can be formed under a number of different conditions.



The Age of Fossils

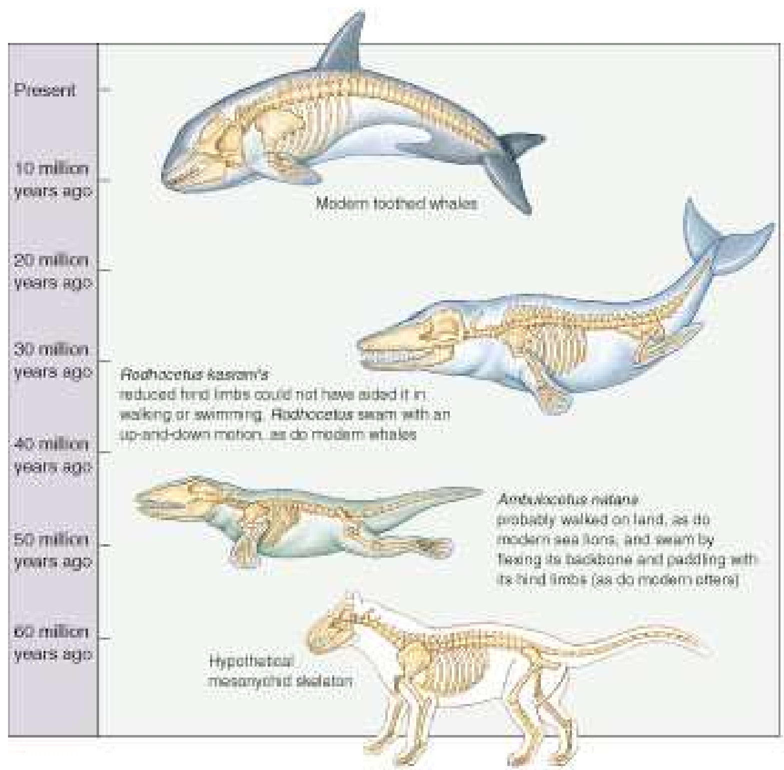
Nicolaus Steno proposed the principle of **superposition** , which states that if the rock strata at a location are not undisturbed, the lowest stratum is the oldest. By using this principle, scientists have been able to put together the *geologic time scale*, a timeline for the order in which different groups of fossils were formed. Today, geologists can often tell a fossil's **relative age** (age compared to other fossils) by referring to the geologic time scale and to records of known fossils.

For certain rocks, scientists can estimate the time since formation, the **absolute age,** by using techniques such as *radiometric dating*. By using both relative age and absolute age, scientists try to make their history of life on Earth as precise as possible. Since not all organisms have left behind fossil evidence, there is an incomplete history of life. Even so, Earth is rich with fossil evidence of organisms that lived in the past.

The Distribution of Fossils

Different organisms lived at different times, since rock strata hold different kinds of fossils in different layers. Today's organisms were different than those of the past, as shown by organisms such as trilobites. Fossils found in adjacent layers are more like each other than to fossils formed in deeper or higher layers – organisms that lived during closer time periods are more alike than those who lived in widely separated time periods. By comparing fossils and rocks from around the planet, scientists can infer when and where different organisms existed.

Transitional Species



The fossil record indicates that species have differed in a gradual sequence of forms over time. This idea is based on *transitional species*, which have features intermediate between those of hypothesized ancestors and later descendant species. For example, whales are thought to have evolved from early mammals. The above hypothesis predicts that there should be fossils that share characteristics of modern whales and of ancient land-dwelling mammals.

Scientists have found several fossils that form a sequence of transitional forms. Comparing these fossils with each other and with modern whales reveals a sequence of differences in the structure of the hind limbs, forelimbs, vertebrae, and skull of each species. Scientists explain these differences as increasing adaptations for life in the water. For example, hind limbs were smaller in later structures and are absent in modern whales except for small, nonfunctioning hip bones.

(Text from Modern Biology, Holt, Rinehart, and Winston)

BIOGEOGRAPHY

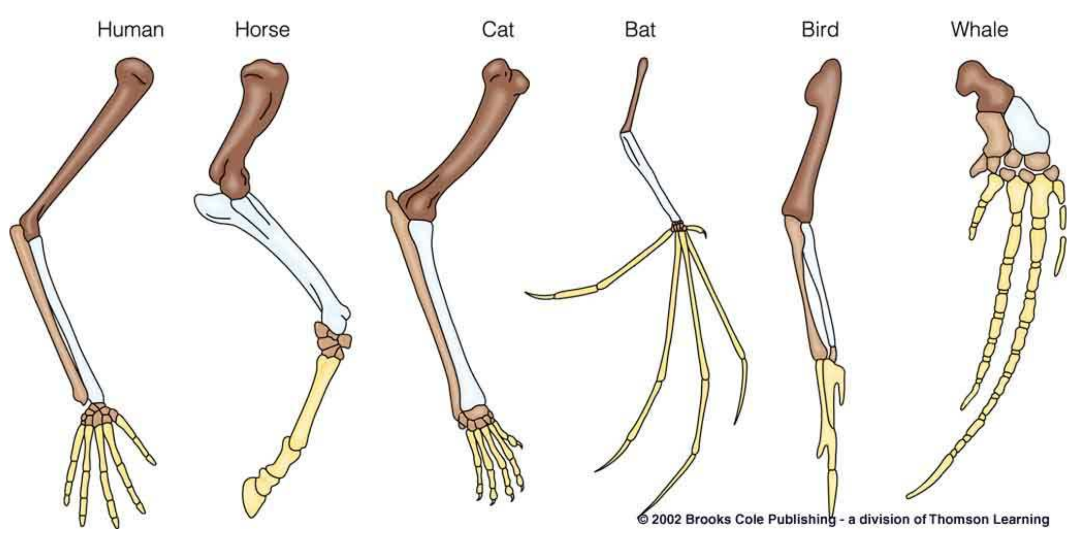
Biogeography is the study of the locations of organisms around the world. When traveling, Charles Darwin saw evidence of evolution in the distribution of organisms. He observed animals that seemed closely related yet were adapted, such as the emu, rhea, and ostrich (below, left to right). The model of descent with modification provides an explanation for these patterns of distribution.



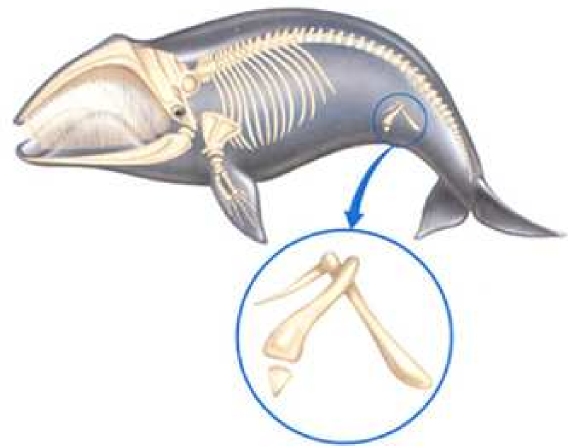
ANATOMY AND EMBRYOLOGY

Descent with modification also predicts the findings of *anatomy* and *embryology*. The bones in the forelimbs of humans and several other animals have a similar structure, although they are used in different ways. One explanation for the similarities is that an early ancestor shared by all these vertebrates had a forelimb with a similar bone structure. As generations passed, different populations of descendants adapted to different environments.

Biologists define **homologous structures** as anatomical structures that occur in different species and that originated by heredity from a structure in the most recent common ancestor of the species. **Analogous structures** have closely related functions but do not derive from the same ancestral structure, but instead evolved independently in each organism.



Further evidence of evolution is found in structures called **vestigial structures** that seem to serve no function, but resemble structures with functional roles in related organisms. For example, pelvic bones of modern whales are nonfunctional, but serve as evidence that the ancestors of whales may have walked on land.



The development of animal embryos is also evidence of descent with modification. Some stages of vertebrate embryo development are very alike, although the similarities fade as development proceeds.

BIOLOGICAL MOLECULES

Organisms that share many traits should have a more recent common ancestor than organisms that share fewer traits. Darwin made this prediction by studying anatomy, but modern studies of biological molecules also support this prediction. By comparing the DNA, RNA, proteins, and other biological molecules from many different organisms, they can look for similarities and differences among the data for each species. The greater the number of similarities between any given species, the more closely the species are related through a common ancestor.

DEVELOPING THEORY

The blending of the theory of natural selection and new understandings of genetics is called the *modern synthesis* of evolutionary theory. Scientists try to model **phylogeny**, the relationships among groups of organisms. Hypotheses are supported when anatomical and biochemical data match the same model.

SECTION 1 REVIEW

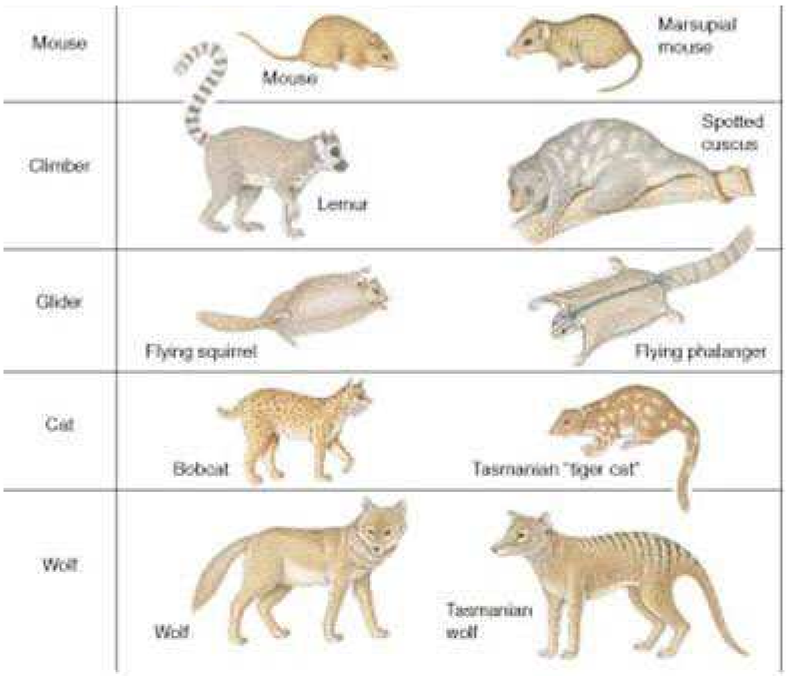
1. Relate several influences about the history of life that are supported by geologic evidence.
2. What evidence supports the hypothesis that whales evolved from land-dwelling mammals.
3. Compare the concepts of homologous structures, analogous structures, and vestigial structures.
4. Explain the evidence of evolution presented by the mammals of Australia.
5. Compare the use of biological molecules to other types of analysis of phylogeny.

CRITICAL THINKING

6. Does natural selection act on vestigial structures? Support your answer.
7. If the DNA of a whale, a hippopotamus, and a camel were compared, what finding would support the model in Figure 15-10?
8. Fly embryos and frog embryos differ from each other more than frog embryos and ape embryos do. What does this imply about how these groups may be related?

SECTION THREE: EVOLUTION IN ACTION

PATTERNS OF EVOLUTION



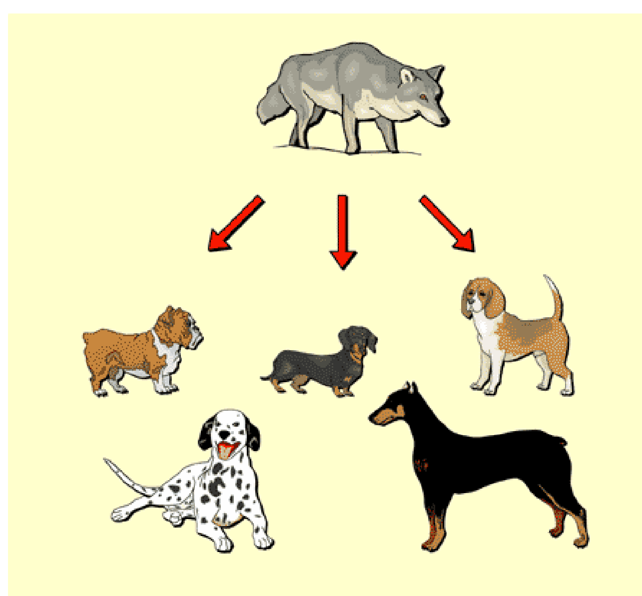
When comparing groups of species, scientists find patterns that are best explained as evolution in process. For example, the process by which different species evolve similar traits is called **convergent evolution**, of which many examples can be found in nature.

Divergence and Radiation

The finches of the Galapagos are another example of patterns of evolution. They model **divergent evolution**, a process in which the descendants of a single ancestor diversify into species that each fit different parts of the environment. Each finch species has adapted so they can live in different habitats and feed on different things. Sometimes, a new population in a new environment, such as an island, will undergo divergent evolution until the population fills many parts of the environment. This pattern of divergence is called **adaptive radiation**.

ARTIFICIAL SELECTION

The process of **artificial selection** occurs when a human breeder chooses individuals that will parent the next generation. Geneticists have analyzed DNA from 654 dog breeds, including ancient dog remains. Their findings indicated that all breeds of dogs share similarities with East Asian wolves. These findings support the hypothesis that humans first selected domestic dogs from a wolf population about 15,000 years ago. Artificial selection is also used to breed plants that will yield a better harvest.



(Text from Modern Biology, Holt, Rinehart, and Winston)

COEVOLUTION

Many species may be evolving at once in a given environment. Each species is part of the forces of natural selection that act upon the other species. When two or more species of evolved adaptations to each other's influence, the situation is called **coevolution**.

Coevolution has resulted in flowering plants evolving so that specific insects will carry pollen to other plants. Additionally, some species have evolved strategies to avoid being eaten, while the animals that eat them have evolved strategies to keep feeding on them.

Humans are also involved in many cases of coevolution. For example, with the increased use of pesticides, humans have killed insects. However, some insects have evolved adaptations to resist the effects of the pesticides – this kind of adaptation is called *resistance*.

SECTION 1 REVIEW

1. Explain how the anole lizard species on the Caribbean islands demonstrate both convergent and divergent evolution.
2. What are the key differences and similarities between natural selection and artificial selection?
3. Give examples of species that are likely to be coevolving. Describe how each species influences the evolution of the other species.

CRITICAL THINKING

4. What is the meaning of *radiation* as used in the term *adaptive radiation*?
5. Draw a phylogenetic tree to match each of the two proposed hypotheses for the evolution of the anole lizards.
6. Propose a reason why some Caribbean islands lack lizard species.

CHAPTER HIGHLIGHTS

Section 1: History of Evolutionary Thought

- Evolution is the process of change in the inherited characteristics within populations over generations such that new types of organisms develop from preexisting types.
- Scientific understanding of evolution began to develop in the 17th and 18th centuries as geologists and naturalists compared geologic processes and living and fossil organisms around the world.
- Among geologists, Cuvier promoted the idea of catastrophism, and Lyell promoted uniformitarianism. Among naturalists, Lamarck proposed the inheritance of acquired characteristics as a mechanism for evolution.

- After making many observations and considering ideas of other scientists, both Darwin and Wallace proposed the theory of natural selection to explain evolution.
- Darwin wrote *On the Origin of the Species*, in which he argued that descent with modification occurs, that all species descended from common ancestors, and that natural selection is the mechanism for evolution.
- Organisms in a population adapt to their environment as the proportion of individuals with genes for favorable traits increases. Those individuals that pass on more genes are considered to have greater fitness.

Section 2: Evidence of Evolution

- Evidence of evolution can be found by comparing several kinds of data, including the fossil record, biogeography, anatomy and development, and biological molecules. Evolutionary theories are supported when several kinds of evidence support similar conclusions.
- Geologic evidence supports theories about the age and development of Earth. The fossil record shows that the types and distribution of organisms on Earth have changed over time. Fossils of transitional species show evidence of descent with modification.
- Biogeography, the distribution of organisms, shows evidence of descent with modification.
- In organisms, analogous structures are similar in function but have different evolutionary origins. Homologous structures have a common evolutionary origin. A species with a vestigial structure probably shares ancestry with a species that has a functional form of the structure. Related species show similarities in embryological development
- Similarity in the subunit sequences of biological molecules such as RNA, DNA, and proteins indicates a common evolutionary history.
- Modern scientists integrated Darwin's theory with other advances in biological knowledge. Theories and hypotheses about evolution continue to be proposed and investigated.

Section 3: Evolution in Action

- Ongoing examples of evolution among living organisms can be observed, recorded, and tested.
- In divergent evolution, related populations become less similar as they respond to different environments. Adaptive radiation is the divergent evolution of a single group of organisms in a new environment.
- In convergent evolution, organisms that a re not closely related resemble each other because they have responded to similar environments.
- The great variety of dog breeds is an example of artificial selection.
- The increasing occurrence of antibiotic resistance among bacteria is an example of coevolution in progress.